Original Article

The plane of the distal femur anterior cortex is a useful index for femoral component rotation in total knee arthroplasty

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ABSTRACT

Objective: To investigate the reference role of the plane of the distal femur anterior cortex in determining the lateral rotation angle of femoral component in total knee arthroplasty (TKA).

Methods: Computed tomography (CT) scan was performed for full length of both lower limbs in 27 patients, and a total of 53 legs were examined by radiological department of the First Affiliated Hospital of Sun Yat-sen University. Case inclusion criteria were as follows: no obvious congenital bone deformity on the lower limbs, no knee purulent infection, and no severe knee deformity after surgery. 3D reconstruction was performed by Mimics 16.0 software for the scan images to calculate the angle between the plane of the distal femur anterior cortex and the Posterior Condylar Line (PCL) (defined as FPA), and the angle between the plane of the distal femur anterior cortex and the Clinical Epicondylar Axis (CEA) (defined as ACA), as well as the angle between the CEA and PCL, known as the condylar twist angle (CTA). Finally, Kolmogorov–Smirnov test and Student's *t* test were used to analyze the measured value.

Results: The average value of FPA was $-4.70 \pm 3.77^\circ$, that of CTA, $+5.04 \pm 2.36^\circ$, and that of ACA, $-9.17 \pm 5.78^\circ$. Each angle measured above has no significant differences in the gender ($P > 0.05$).

Conclusion: ACA was measured to be $9.17 \pm 5.78^\circ$ on the direction of medial femoral rotation, proving that the plane of distal femur anterior cortex plays a relatively accurate reference role in determining the lateral rotation angle of the femoral component in TKA.

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Rotational alignment of the femoral component in total knee arthroplasty (TKA) influences the clinical results observed in long-term follow-up.^{1,2} Improper alignment could cause femorotibial joint instability³ or loosening of the tibial component and is associated with subluxation or dislocation of the patella induced by patellofemoral maltracking.⁴ At present, traditional TKA osteotomy is performed using anatomical marks such as Clinical Epicondylar Axis (CEA), Posterior Condylar Line (PCL), and the Anterior Posterior Line (APL); however, in cases of knees with obvious deformities and severe bone defects, these anatomical axes are usually difficult to be accurately located during surgery, which will also affect accurate component installation. Computer-assisted surgical navigation systems have been developed, but because of the equipment requirement,^{5,6} the systems has not

been widely used, so to improve the accuracy of the traditional TKA in the femoral rotation is increasingly important.^{5,6} The distal femur anterior cortex is an area between distal femur patellar surface and femoral shaft, with length of about 2–3 cm, width of about 1.5–2.5 cm, where anterior notch in TKA often takes place. In this study, full-length CT scanning data of both lower limbs were collected and a professional analytical software was employed to analyze the relationships of the plane of the distal femur anterior cortex with the CEA and PCL, so as to study the reference role of the plane of the distal femur anterior cortex in the installation of femoral component in TKA. It is hypothesized that this plane would provide a more reliable index for femoral component rotation.

1. Materials and methods

1.1. General data

All 27 patients were from the southern provinces of China, including 19 men and 8 women, mean age 69.7 years (range 34–89). All patients underwent a knee computed tomography (CT)

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Fig. 1. A shows the measurements of CTA, ACA, and FPA in the 3D reconstruction, b and c show sagittal and coronal views of the distal femur anterior cortex, respectively.

This figure was made by mimics16.0.

scan in our hospital between January 2011 and December 2013, and all received full-length CT scanning of both lower limbs. Only one case was excluded due to post-operative deformity from previous orthopedic surgery on the right leg. Case inclusion criteria were as follows: no obvious bone deformity on the lower limbs, no knee infection, and no severe knee deformity. CT scanning was performed using a 64-slice CT scanner (TOSHIBA). Patients were asked to remain in the supine position while keeping the lower limbs naturally straight.

1.2. Data analysis

Scanned images of the lower limb were imported into Mimics 16.0 software in DICOM format (Materialize, Belgium), and femur models were constructed through extraction and segmentation of bone CT values; then anatomical axes and the plane of the distal femur anterior cortex were positioned. CEA was obtained by localizing the lateral epicondyle and entepicondylar of the femur on a femur cross section; the connecting line of the two points is CEA (Fig. 1A). PCL was obtained by localizing the most protruding points of the medial and lateral posterior condyle of the femur; the connecting line of the two points is PCL (Fig. 1A). The plane of the distal femur anterior cortex was obtained on the 3D femur model by selecting the distal femur anterior cortex region, and the plane of the distal femur anterior cortex was automatically generated through analytical functions (Fig. 1B and C). The angle between the plane of the distal femur anterior cortex and PCL was defined as FPA, the angle between CEA and PCL was defined as the condylar twist angle (CTA), and the angle between the plane of the distal femur anterior cortex and CEA was defined as ACA. A positive value indicates the direction of lateral femoral rotation, while a negative value indicates the direction of medial femoral rotation.

1.3. Statistical analysis

Statistical analysis was performed by SPSS19.0. The data above respectively were analyzed the values of FPA, CTA, and ACA (mean $\pm$ standard deviation). Normality test was performed using the Kolmogorov–Smirnov test method, and Separate *t* tests compared gender differences, defined $P < 0.05$ for differences are significant.

2. Results

Overall the average CTA was $(+5.04 \pm 2.36^\circ)$, followed normal distribution ($P > 0.05$), in which the male average twist angle of the femoral condyle $(+4.73 \pm 2.06^\circ)$, female twist angle of the femoral condyle $(+6.42 \pm 3.23^\circ)$. Men and women of CTA values do not meet

Fig. 2. The distribution of ACA followed normal distribution. A negative value suggests the direction of medial femoral rotation, a positive value suggests the direction of lateral femoral rotation.

This figure was build by software GraphPad Prism 5.

the homogeneity of variance ($F = 5.487$, $P = 0.023$, $P < 0.05$), by Calibration *t* test, the CTA gender difference was not statistically significant ($P = 0.076$, $P > 0.05$).

Overall the average FPA was $(-4.70 \pm 3.77^\circ)$, followed normal distribution ($P > 0.05$), in which the male average $(-5.25 \pm 3.70^\circ)$, female $(-3.31 \pm 3.70^\circ)$. Men and women are in line with FPA homogeneity of variance ($F = 0.147$, $P = 0.703$, $P > 0.05$), by Independent-Samples *T* Test, the gender differences in FPA were not statistically significant ($P = 0.090$, $P > 0.05$).

Overall the average ACA was $(-9.17 \pm 5.78^\circ)$, followed normal distribution ($P > 0.05$), in which the male average $(-9.63 \pm 4.94^\circ)$, female $(-8.01 \pm 7.60^\circ)$. Men and women of the femoral condyle twist angle values do not meet the homogeneity of variance ($F = 6.374$, $P = 0.015$, $P < 0.05$), by Calibration *t* test, the gender differences in ACA was not statistically significant ($P = 0.455$, $P > 0.05$). The distribution of ACA measurement results is shown in Fig. 2, and 62.3% (33/53) of the values concentrate between 8° and 14° .

3. Discussion

Total knee arthroplasty (TKA) is currently an effective way to treat severe degenerative knee arthritis, and the reconstruction of good lower limb mechanical force lines is the key determining the service life of a component. At present, traditional TKA osteotomy is performed using anatomical marks such as CEA, PCL, and APL; however, in cases of knees with obvious deformities and severe bone defects, these anatomical axes are usually difficult to be accurately located during surgery, which will also affect accurate component installation. It was found during surgery that the plane of the distal femur anterior cortex was clearly exposed, and would not have anatomical variations due to pathological changes of the knee. For this reason, it was assumed and expected that studying the anatomical features of the plane of the distal femur anterior cortex and its relationships with anatomical mark lines such as CEA and PCL would allow for good guidance for accurate installation of knee prostheses.^{7,8}

In this study, the results showed that the gender differences in CTA, FPA, and ACA were not statistically significant, and the CTA of the research subjects was $5.21 \pm 2.53^\circ$, larger than the average 3° reported by foreign studies; other domestic studies have reported similar results, proving that the CTA of Chinese people is greater than that of people of other ethnicities, and that the routine 3° lateral rotation osteotomy for femur component in TKA is not suitable for anatomical features of Chinese people. The anatomical image of the plane of the distal femur anterior cortex was obtained using medical analysis software, and the angle of this plane with PCL in 3D space was measured to be $-4.70 \pm 3.77^\circ$ and the angle with CEA was

$-9.17 \pm 5.78^\circ$. It can be seen in Fig. 2 that the ACA measurement results were mostly distributed around 9° of the direction of medial femoral rotation. During surgery, this plane of the distal femur anterior cortex can be used for direct individual evaluation and adjustment of the femur component lateral rotation angle.

It is known that the distal femur has a complex anatomical morphology and whether a femur component can have a good installation position in TKA requires referring to anatomical axes to determine the angle of lateral femoral rotation. The surgical transepicondylar axis (STEA) has previously been considered as the most valuable reference axis for femur component rotational force line in TKA; however, Park proposed in 2014 that positioning the femur component rotational force line based only on STEA may cause component malposition, and is more likely to cause excessive lateral rotation of the femur component compared with PCL and APL⁹; thus, more anatomical axis angles need to be referred to when determining the lateral rotation angle of the femur component. In addition, most patients' knees have different degrees of joint degeneration before surgery combined with varus or valgus deformity, massive osteophytosis, or different degrees of posterior condylar defects that severely affect intraoperative determination of anatomical axes such as PCL and CEA. Moreover, most prosthetic osteotomy instruments use a posterior condylar positioning reference system, and a severe posterior condylar defect on the diseased knee may greatly affect the accuracy of femur component lateral rotation positioning. At present, most prostheses provide osteotomy reference instruments for 3° lateral rotation, whereas according to the results of this study, the CTA of Chinese people is not a 3° lateral rotation and differs greatly among individuals.

All available evidence suggests that the currently used posterior condylar positioning produces relatively large errors and is capable of causing an inaccurate lateral rotation angle after femoral osteotomy, resulting in component installation malposition. Hence, precisely analyzing each angle of anatomical axes at the distal femur of the knee before surgery to determine the component lateral rotation angle is extremely important for accurate installation of the femur component. Preoperative analysis of distal femur anatomical axis angles of knees for TKA patients can be achieved through CT examination, and the measured data can be used to effectively increase osteotomy accuracy.¹⁰ The plane of the distal femur anterior cortex is a relatively easy anatomical mark to position during TKA. A 3D reconstruction of a knee model using CT data was conducted in this study, and the angle between the plane of the distal femur anterior cortex and CEA was measured to be $9.17 \pm 5.78^\circ$ on the direction of medial femoral rotation, proving that the plane of the distal femur anterior cortex can accurately position CEA. As long as the angle between the two is accurately measured before surgery, the plane of the distal femur anterior cortex can then be used as the base plane during surgery to accurately adjust the lateral rotation angle of femur component, so as to achieve the ideal femur component installation position.

This study also has certain shortcomings, such as a small sample size, the distal femur morphology was not specifically categorized,¹¹ and whether different femur shaft morphologies also

affects the size and direction of anterior cortex also needs to be confirmed by more experiments¹²; moreover, the currently used measurer designed to measure the plane of the distal femur anterior cortex is relatively simple and needs to be redesigned for greater accuracy, and more cases are needed to conduct follow-up studies.

Conflicts of interest

The authors declare there is no conflicts of interest regarding the publication of this paper.

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